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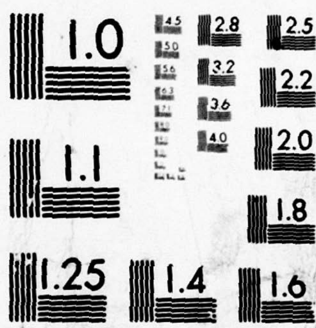

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9 Research note,

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6 THE ROLE OF THE HYSURCH SURVEY SHIP IN THE PRODUCTION OF NAUTICAL CHARTS

by

10 Edwin A. Olsson
~~and~~
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Contract N62306-67-C-0122
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Abstract

This note describes the makeup and operation of the shipborne Cartographic and Reproduction subsystem for the HYSURCH system. The survey ships are devoted predominantly to the collection and processing of hydrographic data. Shipborne cartographic equipment and chart reproduction facilities are minimal because these functions will normally be performed on land.

EXPLANATORY NOTE

This is one of a series of Engineering Reports that document the back-ground studies to be used in a system design for HYSURCH (Hydrographic Surveying and Charting System). In general, these reports cover more detail than that finally necessary for a system design, Any subsystem recommendations contained in these reports are to be considered tentative. The reports in this series are.:

RN-22	Soundboat Navigation Equipment and Strategy for HYSURCH by John Hovorka
RN-23	The Role of the HYSURCH Survey Ship in the Production of Nautical Charts by Edwin A. Olsson
RN-24	An Investigation of Side-Looking Radar and Laser Fathometers as HYSURCH Sensors by Jack H. Arabian
RN-25	A Computation Center for Compilation, Revision and Presentation of Hydrographic Chart Materials by Edwin A. Olsson
RN-27	Parameters for the Evaluation of Sonar Depth Measurement Systems by Joel B. Searcy
RN-28	Tidal Measurement, Analysis, and Prediction by J. Thomas Egan and Harold L. Jones
RN-29	Applications of Aerial Photography for HYSURCH by A.C. Conrod
RN-30	Sounding Equipment Studies, by Leonard S. Wilk

RN-31 Error Analysis of a Dual-Range Navigation Fix and Determination of an Optimal Survey Pattern by Greg Zacharias

RN-32 Tethered Balloons for Sounding Craft Navigation Aids by Lou C. Lothrop

These reports were prepared under DSR Contract 70320, sponsored by the U.S. Naval Oceanographic Office Contract Number N62306-67-C-0122. The reports are meant to fulfill the reporting requirement on Sub-system selection as specified in the MIT proposal submitted in response to the Oceanographic Office Request for Quotation, N62306-67-R-005.

Acknowledgement

The authors wish to express their appreciation for the openness and helpfulness which they found throughout the mapping and charting community. This atmosphere permitted the establishment of meaningful conclusions regarding cartography at sea today and in the future which reflect the opinions and convictions of the bellwethers of the field.

Acknowledgement is made of the significant efforts of Mr. Gerard McWeeney, Mr. Fred Taylor and Mr. George Bernard of the MIT Instrumentation Laboratory who studied in detail the state of the art in cartographic and reproduction equipments and evaluated the operations of those equipments at sea.

Table of Contents

Section I Requirements for High-Speed Hydrographic Surveying and Charting

The U.S. Navy is committed to the production of reliable charts for the coastal waters of the world outside of the territorial waters of the United States. These charts serve American military interests and American and world-wide maritime interests.

The National Bureau of Standards[1], under contract to the Navy, has conducted a study of DOD's requirements[2] for charts in the near future and a study of the Naval Oceanographic Office's current capabilities. These studies have indicated the dimensions of the large gap by which capability lags requirements. The Naval Oceanographic Office has prescribed in the MIT HYSURCH work statement[3] that current capabilities of hydrographic surveying and charting must be improved by a factor of ten. As a rule of thumb, this improved performance could be achieved by three survey-ship operations each surveying and charting 100 nautical miles of coastline per week on a nearly continuous basis. The desired level of activity may also be described as the production of four 34" by 48" 1:50,000 scale charts per week by each survey ship. This description of the task is used to size the Cartographic and Reproduction Subsystem of HYSURCH.

The generation of charts requires three major activities: the compilation of a hydrographic chart of coastal waters, the compilation of land-map coverage for the area along the shore, and the merging, editing and reproduction of the combined product.

It was originally thought[3] that all of these operations would be performed at sea, so that each survey ship would constitute an essentially independent seaborne mapping facility. In the course of the study, however, it has become apparent that the survey ship is only part, albeit an important part, of a basically land based operation. Section II of this report outlines the proposed HYSURCH map compilation and reproduction process, and the remaining sections describe the

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* Numbers refer to Bibliography entries.

shipboard activities and equipment in greater detail. The Appendices give a brief summary of the base-plant functions and the operations involved in producing line maps and pictomaps*.

Section II The Implementation of HYSURCH

The anticipated sequence of operations in a HYSURCH mapping project is shown schematically in Figure 1. There are a number of possible paths leading to several types of output product; the choices among these possibilities are dictated by economic considerations, the urgency of the project, the extent, quality and format of existing map coverage, and many other factors.

One output product required under all circumstances is the "planning document", used for directing the hydrographic data collection activity. This map will be needed on the survey ship only, and in very limited quantity. It need not be particularly accurate or elegant, but it must be produced in as short a time as possible - 24 hours is the stated requirement. A simple direct copy of an existing map is the obvious choice, if such a map exists. Otherwise, as indicated in Figure 1, we believe that a photo index (an uncontrolled mosaic of unrectified near-vertical aerial photographs) is the only solution possible within the allotted time. The index would be constructed from existing or newly obtained photographs, and it should provide the field survey personnel with an adequate base on which to construct their hydrographic data net.

The final map product will be either an orthophotomosaic (pictomap) or a conventional line map*. Under normal circumstances the base plant will produce the land portion of the map, either by revision of existing

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* The term line-map is used in this report to designate the drafted line/symbol product as differentiated from the pictomap (or orthophotomap) which is a photographic product. Refer to Appendices A and B for further background on the subject.

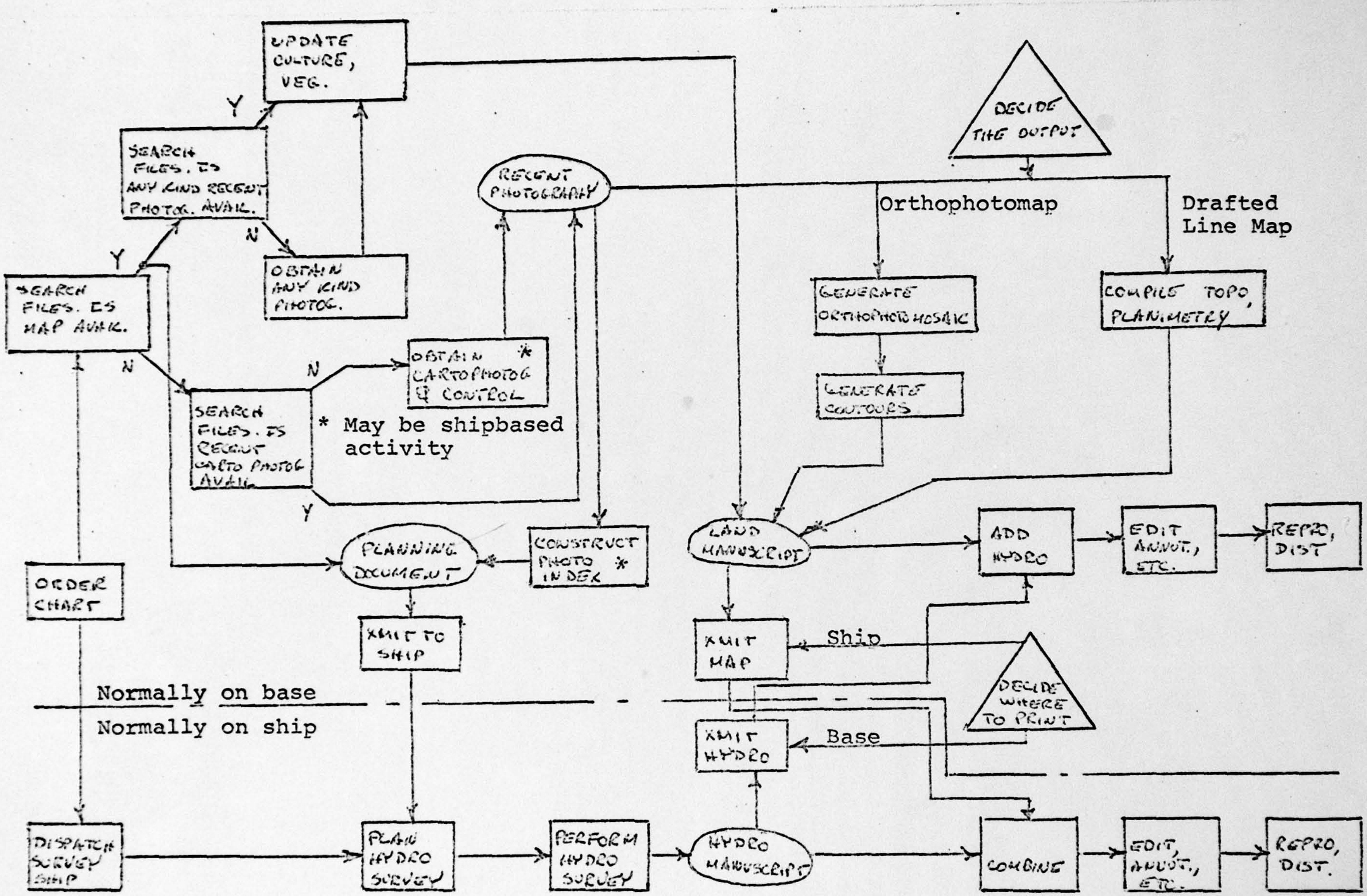

Fig. 1 Flow Diagram of Landbased and Shipborne HYSURCH Activities

coverage or by generation of a completely new map from aerial photography. At the same time, the survey ship will collect and compile the hydrographic data. In routine peacetime operations the hydrographic portion will then be transmitted back to the base plant where the final map will be edited and reproduced. All long runs of "archive-quality" charts will be produced in this manner. However, if the map is needed urgently in the field, color separations of the land portion may be transmitted to the survey ship, and the merging, editing and reproduction operations may then be performed at sea. The HYSURCH survey ships will also have the capability to generate new land maps or revise old ones by manual methods, in an extreme emergency, but this procedure would seldom be employed.

Section III Treatment of Hydrographic Data

HYSURCH is expected to draw upon two types of sources of bathymetric information: discrete soundings and continuous graphics. The discrete soundings will include individual depth(and other) inputs as a function of position. The graphics include photographs - infrared shoreline photography and color ocean photography for bottom information - and other graphics, such as sidelooking sonar which portrays slant range as a function of time.

The discrete information will be reported to the hydrographic compilation center in digitized format. The pertinent information in the graphics will be converted to digited format before being submitted for compilation. The compilation operation will be performed in a digital computer. The computer will supply a graphic or graphics of the hydrographic portion of the chart at appropriate scale and to specified accuracy.

In this section, we describe the data handling system for processing input sounding data and digitized graphic data, for compilation of a hydrographic chart as an image in computer memory, and for the generation of a graphic output. The hardware details are the subject of a separate Research Note (RN-25) entitled "A Computation Center for

Compilation, Revision and Presentation of Hydrographic-Chart Materials".

3.1 Input Data

The primary hydrographic input mechanism of HYSURCH is expected to be a diversified fleet of survey platforms (various boats and helicopters) which, under direction from the survey ship, comb the survey area and transmit depth (and perhaps other parameters such as bottom characteristics, sea state, temperature or salinity) to the survey ship as a function of position within the navigation grid. On the survey ship, time information is added to the record to permit later correction for tide and current as measured at a number of buoy stations and periodically transmittted to the survey ship.

The input data is digitized on the survey platform where an analog depth-sounder record is produced in addition to the transmitted digital data. Consideration is being given to tape recording the digitized data aboard the survey platform as well. The platform-to-ship transmission will be coded redundantly so as to minimize loss of data due to fading or drop out. Upon reception at the survey ship the messages are directed to a computer for decoding and compilation. It is possible that the total received transmissions should also be recorded on board the survey ship. The purpose of the various tape recordings is to preclude having to resurvey an area where transmission is lost; the purpose of redundant transmission is to save the cost of multiple redundant records* through reliable communication. The analog sounder records will be used to correct or authenticate suspect digital sounding information; the digitized sounder is subject to occasional errors in the presence of multiple returns.

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* The various digital records and redundant transmission represent either/or solutions to reliable data handling. RN-25 will treat this area in further detail.

3.2. Graphic Input Data

The graphic information collected in the hydrographic survey must be converted to digital form and read into the computer for compilation. There are several possible methods of handling these operations.

The simplest graphic records to process are those obtained from side-looking sonar. These records are valuable for recognition of shapes beneath the ocean surface, but a single side-looking sonar cannot give depth or position information because it measures only slant range. A pair of records of the same area, made from stations of known relative position, must be used to obtain the required data. Special automatic equipment could be constructed for this purpose, but it is more practical to measure the two records independently with a suitable manual digitizer and program the computer to extract the depth and positon information. A wide variety of existing digitizers could be used, as the required accuracy is only a few thousandths of an inch; one example is the Concord Control Universal Graphic Processor[4], a seaworthy digitizer which is particularly useful in that it can also be operated in reverse as an automatic plotter.

Aerial photographs taken from the HYSURCH helicopter will be used to locate the survey navigation buoys with respect to shore landmarks or other control. The photographs will probably be vertical or near-vertical; in any case, the buoys must lie in a single plane (the ocean surface) and simple rectification - graphic or digital - is all that is necessary to convert photographic coordinates to map coordinates. The buoy positions could therefore be transferred directly to the base map with simple Sketchmaster equipment (e.g., Aero Service Corp., Zeiss) or with the slightly more versatile Rectoplanigraph (Fairchild Camera and Instrument Corp.). However, inasmuch as the buoy coordinates will surely be required in digital form by the computer for compilation of the hydrographic data, it would seem

more practical to measure the buoy positions and the control points directly on the photographs, insert this information into the computer, and perform the rectification analytically. If the known control points are at sea level, the photographic measurements can all be made with the same digitizer used for sonar records, but if the control is at significant elevation parallax corrections are required and the measurements must be made to higher accuracy. In the latter case an x-y lead screw comparator with microscope eyepiece could be used (e.g. David Mann Co., Gaerttner, McPherson, etc.) These instruments allow measurements to $\pm$ 1 micron accuracy over 9 x 9 -inch or larger areas, and they can be equipped with shaft encoders for automatic digital readout.

Infrared photographs will probably be used for accurate shoreline determination. This photography is most advantageously taken from high altitude, in which event the reduction to chart format would be performed at the base plant. If the photographs are taken by the HYSURCH helicopter, the projection of the shoreline onto existing control could be made by either of the two procedures described above for buoy location. Again, the digital approach would probably be preferred because the shoreline will require correction for tides in many areas.

Under ideal circumstances it may be possible to obtain underwater topographic information from aerial photographs. Rocks, shoals, channels, and other features, are often visible, and stereoscopic measurements on pairs of photograph can sometimes be used to determine depths. This operation is exactly analogous (aside from the necessary refraction correction) to topographic mapping of land areas from aerial photographs. Because ideal circumstances seldom prevail, it is more likely that suitable photographs will be obtained by the HYSURCH helicopter which is always present than by aircraft dispatched by the base plant, and it is therefore desirable that the survey ship have suitable

analysis equipment. If only spot depths are required, it will be most expeditious to measure the desired points in the individual photographs with the x-y comparator and solve for the depths with the computer. However, if depth contours are required, some kind of stereoscopic plotting instrument should be used. Since the degree of utilization of this equipment is not expected to be high, we believe that it should be relatively simple and inexpensive; needless to say, it must also be capable of withstanding, and being used in, the seaborne environment. These considerations point to the choice of a manual orthographic plotting instrument, such as a radial line plotter (Hilger and Watts, Philip B Kail Associates), the Kail KEK stereoscopic plotter, or the Zeiss Stereotope.

3.3. Compression, Translation and Storage

The definition of types and numbers of survey platforms in a fleet is one of the study tasks for HYSURCH at MIT. The results of this task are not as yet complete, so for purposes of analyses the authors have assumed a maximum of fifty independent transmitting platforms. For typical message rates, the resulting input data rate is well within the capabilities of the small-to-medium-sized computers considered for HYSURCH. There will be a considerable efficiency realized in computer operations, however, if the input data arrives at scheduled rather than unscheduled interrupts. Consequently, survey platforms will transmit data on command from the computer in the survey ship. This technique not only simplifies the organization of the compuer but also permits immediate identification of a lost message.

The data rate from any given survey platform is expected to range from one message per second to five messages per second depending upon platform speed, local depth, and sonar beam-width. For flat or gradually sloping bottoms, the depth data will be relatively uninteresting. As a consequence, the first operation

to be performed by the computation facility is to filter the incoming data; i.e., accept the first depth record, reject subsequent records until a given differential depth is realized, accept that new depth, etc.

Those depth data points which survive the filtering (data-compression) operation, are translated from navigation grid coordinates into absolute coordinates; i.e., latitude-longitude or UTM, and stored in a magnetic drum or disc memory. This data is also tagged with time information until the tide correction can be determined and applied.

3.4 Computer Installation

The current design concept for the HYSURCH computation facility includes two (probably identical) computers working with shared drum, disc, and/or core memory. Computer I fulfills the functions of decoding, filtering, translation and matrix storage described in section 3.3. Computer II is devoted to survey monitor (described in section 3.5), editing for manuscript output and outputting. In the event of failure of Computer I, Computer II can take over Computer I tasks in a manner of milliseconds with little or no data loss, monitor can be performed in a backup method, and chart production can be accomplished off line.

3.5 Monitor and Evaluation

The computational facility includes programmed capability to decide when coverage is overly dense, when data is inconsistent, when individual areas are completely surveyed, and similar questions. A visual monitor and a command interface with the programmer/cartographer staff displays this information and allows local control of the fleet of survey platforms either verbally or automatically.

Display will take two forms: a typed message from the computer; and a graphic presentation(hard copy or CRT) which permits the survey directors to use their own judgement. Typical messages

would request widening or closing of lane spacings. Typical graphics would display depths along adjacent boat lanes. In the back-up mode, with only one computer in operation, only the graphic output would be provided.

3.6 Editing and Output

When an area has been completely surveyed, the digital record can be further condensed by the application of the same filtering logic in the direction normal to the survey tracks as was previously applied along the tracks. When this record is corrected for tide, it represents a map of accurate locations of specific depths and other information. Depending on the output scale and the interests of the user, the image map may be further edited to supply specific bathymetric contour lines and spot depths to specific criteria. The record will also include identified locations of shorelines, beacons, hazards to navigation, etc.

The form of the final output of the hydrogrpahic operation depends on whether map production is to be performed at sea or at the base plant. The usual situation will be the latter, in which case the most efficient procedure is simply to transmit the edited digital record, either by radio data link or by physical transfer of magnetic tape.

If the map is to be reproduced on the ship, color separated masters are required. The digital hydrographic record will then be converted to graphical form by means of facsimile reproduction, an incremental plotter (such as the Concord Control Universal Graphic Processor mentioned in section 3.2), or a point/symbol plotter (e.g. Calcomp Plotter). This type of graphic output is required in all cases as a checkprint of hydrographic area coverage.

Section IV Land Mapping

The type of map presentation accorded land areas in U.S. Navy charts varies considerably. One finds at least Class B topographic coverage in the better Combat Charts. One can also find sketchy artistic coverage (with good positional accuracy for landmarks) of the coastal strip in many H.O. charts. The inventory of the Navy Oceanographic Office includes a wide assortment of presentations falling between these extremes. The particular format appropriate to a given chart is a function of the file materials available and the use to which the chart is to be put.

The effort required to generate the land portion of a given chart varies dramatically with the type of format desired and with the extent of existing map coverage. If another agency has recently completed a map of the area at appropriate scale, either no additional cartographic effort is required to provide land-area coverage for a nautical chart or, at worst, some additional annotation may be required to render the existing map suitable for Navy purposes. If an area has been well-mapped previously but natural or man-made changes have accumulated to a significant extent in the intervening time, a relatively simple map revision procedure will produce a satisfactory chart. If an area has never been mapped, or has only been poorly mapped, it is possible that a complete cartographic exercise will be required: photography, establishment of control, compilation of topography and planimetric detail, identification of structures, landmarks and vegetation and annotation and editing of the resulting product.

4.1 Ship or Base Plant

The study contract work statement[3] states that land mapping will be performed by the sea-going facility at the same 100 n.m -of-coastline-per-week rate as is required for hydrographic charting.

There are a number of computer-oriented photogrammetric equipments currently available which will produce orthophoto-maps (pictomaps) fairly automatically from well-controlled cartographic-quality aerial photographs. Some of these equipments will also accommodate oblique and panoramic photographs. The various manufacturers (and users at ACIC, AMS-GIMRADA, RADC, and DIA) agree that with a relatively small cadre of experienced people (cartographers, computer operators and others) and with a reasonable amount of this (relatively expensive) equipment, one could expect to produce pictomaps at the required 100 n.m. of coastline (by a nominal 15 n.m. inland) per week rate. It is true that none of the presently existing equipment could be expected to operate on a moving ship, but "seaworthy" versions of at least some of the apparatus could probably be developed in the available time.

Similarly, it is clear that the more conventional procedures of manual compilation to produce line maps from aerial photographs (using multiplex projection equipment) could be employed to meet the HYSURCH goals; if enough operators and enough projectors are used simultaneously, any rate of map production could theoretically be achieved. Again, none of the existing multiplex equipment would work on a moving platform without substantial alteration, but there is reason to believe that such modifications could be made, or new designs built, before 1971.

Now, however, having established that this novel, mobile map-production facility is possible on paper, one must consider the relative efficiency, reliability, and cost of the shipboard versus the more conventional base-plant operation. The equipment capable of accomplishing the mapping objectives is expensive, sensitive and intricate; cartographic talent is scarce, and retention of adequate maintenance personnel is a severe problem. All of these resources must be fully utilized in a salutory environment if HYSURCH is to represent a sensible, economic solution to the coastal mapping problem. In light of the infrequent projected

requirement for combat charts in unmapped areas[5,*] (the principal new land map requirement), it would be extremely inefficient to equip all hydrographic survey ships with identical, independent, complete land mapping facilities. The complement of equipment and personnel required for a full land-mapping operation would certainly be largely wasted during the majority of surveys where little or no new land coverage is required.

Instead, an integrated operation is suggested, in which all survey missions are supported by a central base plant facility having complete, automatic orthophoto capability in addition to conventional line-map equipment**. All photographic processing, compilation and annotation of land maps is done in this central facility; when map reproduction is to be performed on the survey ship (see section 2), color-separated masters of the land map portion are delivered from the base plant to the ship. The survey ships will be equipped and staffed to perform a simple revision operation for the land portion of a chart in an emergency, but it is expected that this capability will rarely be exercised.

4.2 Shipboard Equipment

The land portions of the hydrographic chart will normally be handled in graphical form on the ship. Revisions, when necessary, will be based on recent aerial photography and will be performed directly on the graphic, rather than being handled digitally in the manner of the hydrographic data.

Line-map revisions can be performed with some of the same equipment described in section 3.2 - the sketchmasters and Rectoplanigraph for planimetry and the radial-line, KEK, and Stereotope stereo plotters for topography. This equipment is relatively simple to operate, rugged, and inexpensive.

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* From Reference 5, a requirement for new photogrammetric compilations in less than 20% of the surveys may be deduced.

** Some of the functions of the base plant are detailed in Appendix C.

All that is required is to sketch the revised information over the existing base map.

Pictomap revision is obviously more complicated. For perfect matching of new photography to the existing map, orthophoto-generating equipment would be required, but for field use it should be acceptable to use segments of rectified near-vertical photographs. One of the many rectifying printers should thus be included in the ship's equipment. Some kind of rudimentary edge-enhancing printer is also required to match the image processing which was used in the production of the original map. Finally, an automatic dodging copier (Fluorododge, LogEtronics) should be available to assist in the difficult process of matching photographic density at the edges of the revised section. The final mosaicking of the manuscript can be done manually. This whole operation will require the attention of highly skilled personnel, and it should be undertaken in the field only under unusual circumstances.

One exception to the all-graphic approach might arise when only a few x,y,z coordinates of specific points are required. In this case it would probably be easier to use the procedure suggested for spot depths in underwater photography (section 3.2), namely comparator measurement of the individual photographs and computer calculation of the desired points. The same equipment would be used for land height and water depth measurements - the same geometric problem is involved.

Section V Editing and Reproduction

A multi-color chart is normally produced through the use of a number of color-separated masters which separately control the application of the various INKS dyes to the chart stock. The color separated masters are the product of the merging of land-map and hydrographic-chart manuscripts, so color-constituted as to vividly project the more important information to the user. The hydrographic portion of

the map is principally found in the black and blue masters: black for annotation and symbology, blue for bathymetric contours and shading. The land portion of the map will probably display intelligence on all of the color masters.

The traditional method of chart reproduction is offset lithography, a process involving large presses, liquid inks, and lengthy set-up procedures. U.S. Navy experience with lithography at sea has not been overly encouraging, and it is evident that, under normal circumstances, it would be greatly preferable to reproduce hydrographic charts at the base plant. Since all land mapping will normally be performed at the base plant as well, the only logical procedure is to send the hydrographic data back to the base plant for merging, editing, and reproduction. Normal lithographic reproduction techniques can then be used, and a high quality printing job is assured.

If field reproduction of maps is required for combat or other urgent purposes, the merging and editing processes should also be performed in the field. In this case, the finished land map portion will be transmitted to the survey ship as color separations, either by radio facsimile or by courier. The survey-ship personnel will then combine the hydrographic and topographic masters, perform rudimentary final editing, and produce the finished color separations.

Map reproduction on the survey ship could be accomplished by lithography, but a more satisfactory process would be desirable for the reasons mentioned at the beginning of this section. The high-speed five-color electrostatic map printer being built for U.S. Army RACOMS system by Harris Intertype Co. does not appear suitable for Navy use in that its image size (22 x 29 1/2 - inches) is too small, its resolution and registration capabilities are inadequate, and it makes use of ~~liquid inks~~. An advanced version (Miehle-Goss-Dexter Inc.) will have the same drawbacks. It now appears, however, that multi-color dry electrostatic copiers could be built for Navy use by 1971. Xerox has a developmental five-color printer which could produce the required 34 x 48 - inch charts with color registration to 0.005 - inch and resolution of at least 200 lines per inch.

RCA is believed to have a similar copier under development. It is strongly recommended that a fixed-price procurement competition be initiated among RCA, Xerox, and any other qualified vendors for a shipboard map printer for HYSURCH. This printer would be extremely useful in all phases of the survey project for proofs and map copies. Coupled with radio facsimile equipment, it could be used on every Navy ship for rapid dissemination of maps and other graphics.

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Appendix A Development of Land Maps From Photographs

In Figure A-1 are illustrated the major steps involved in using aerial photography to generate or update existing maps. The process chosen depends upon the quality of file material and the desired product.

This appendix describes the various processes including various options for several. Comparison of time and equipment required for different techniques is presented in Table A-1. This comparison is based on the requirement to chart an area whose dimensions are 30 n.m. by 100 n.m. (four 34" x 48" charts scaled at 1:50,000); of this area one-half represents land and must be mapped. It is assumed that the scale of the photography and the scale of the charts are 1:50,000; this represents approximately 3100 square inches of coverage or approximately 100 32-square-inch models.

A-1 Orthophotomaps from Aerial Photography

If no suitable maps are available in file, aerial photography, through the use of existing ground control, may be transformed into orthophotomaps (orthophotographs and contours). The mosaic of orthophotographs may be treated by a photographic pictomap process*, in order to produce the basis for color separations and a color chart. The orthophotomap may be manually treated in order to enhance features not easily discernable on the pictomap. Annotation must also be added. The orthophotomap, which may be more or less useful than a line map depending upon circumstances, represents the most rapidly producible product.

The rapid generation of orthophotomaps generally requires automatic photogrammetric machines such as the Bunker-Ramo UNAMACE, the Bendix-Nistri AP-11C or the Raytheon-Wild B8-Stereomat . (The Beam Orthophotoscope is an alternative semi-automatic device for the preparation of orthophotos; it could probably be altered to provide altitude information in a form suitable for a computer to process into contours, but it would

* For description of pictomap process, see Appendix B.

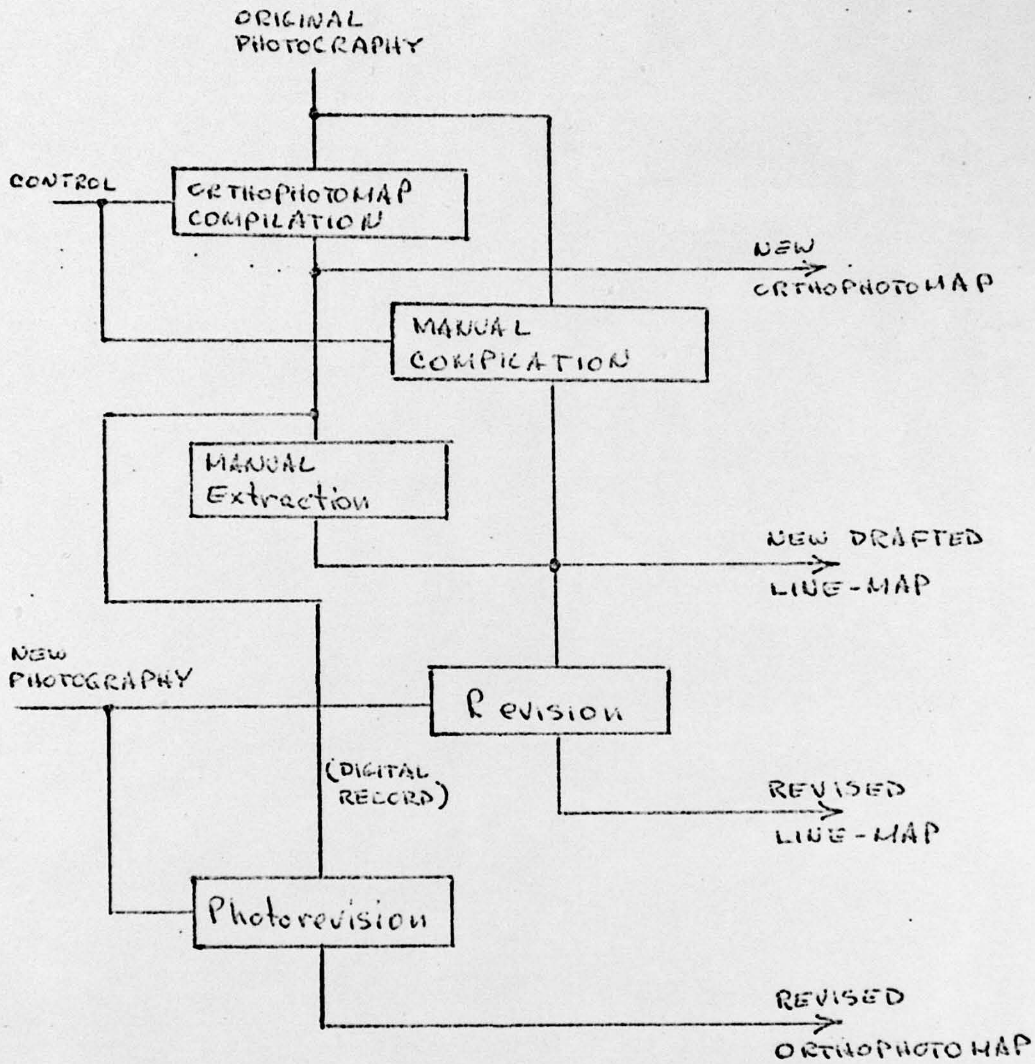

Figure A-1 Photogrammetric Operations in the Preparation or Revision of Land Maps

	Equipment	Cost	Personnel	Operation Time	Remarks
New Orthophotomaps	UNAMACE Stereomat AP-11C	~$500K	Cartographers Computerers PI	~144hrs	Least Operator Fatigue
Line-Maps From Orthophotomaps	None	—	PI	~288hrs	Plus 144 hrs. for Orthophotomap From Photographs
New Line-Maps	Kelsh, B&L Wild, Zeiss OMI, etc	$50K	Cartographers PI	400-500hrs	Greatest Operator Fatigue
Revised Line-Maps	Paper Print Stereo Comp, (i.e.HilgerWatts)	$10K	PI	40-50hrs	
Revised Orthophotomaps	Orthophotoscope Gigas-Zeiss or OMI	$100K	—	~120hrs	Old Digital Record required.

Table A-1 Comparison of Various Land-Map Processes

perform more slowly than the automatic equipment, albeit more cheaply.)

The automatic machines cost in the region of $500,000. The generation of maps requires mensuration of the photographs, block adjustment, compilation of planimetry and topography, mosaicking, pictomap processing, enhancement and annotation; the operation requires good cartographers supported by computer operators and photointerpreters.

By prudent utilization of one of these expensive automatic photogrammetric equipments, four 1:50,000 scale orthophotomaps can be produced in approximately six 24-hour days. (The UNAMACE, AP-11C, and B8 Stereomat all operate at approximately the same basic speed.) This time estimate for producing land maps using automatic machines is based on sequential measurement, orthophoto compilation, contouring and annotation/enhancement of the four charts from 1:50,000 scale photography. Mensuration will be performed off-line, not using the automatic photogrammetric equipment; compilation will be performed on the automatic equipment; contouring will be performed as a background program on the automatic-system computer or on an off-line computer after the compilation is complete; annotation/enhancement will be performed off-line as the orthophotomosaics are generated. The complete operation is expected to take approximately 100 hrs of machine time and as much as 24 hours of measurement and 24 hours of photointerpreter activity before and after each orthophotooperation.

This estimate is supported by production-rate information from the UNAMACE staff at AMS-GIMRADA*. If UNAMACE is used sequentially for mensuration of photographs, production of the orthophotos and production (in the contouring mode) of the contours, approximately 1 hr. per (8 inch by 4 inch) model is required for each operation. To map 3100 square inches, approximately 100 hrs. is required for each operation or 300 hrs. for the orthophotomap. Additional time is required off-line for pictomap processing, enhancement and annotation. These numbers, derived from an operation when

* Conversation with Mr. John Mayer and members of his staff in June 1967.

UNAMACE is used for everything, probably represent a maximum estimate: the mensuration operation may surely be performed off-line on less expensive equipment; the contouring can be performed as a background program in the Bunker-Ramo computer using the digital data acquired in the last compilation (if not in the BR-133, surely in the more powerful Bendix AP-11C-1 computer); compilation may even be performed from smaller scale photography and the product enlarged. As described above the 6 day (144 hr.) figure appears to represent an accurate estimate.

A-2 Line Map* from Orthophotomap

If for various reasons, a line map is required, then the orthophotomap (no pictomap process or enhancement) may be over-layed with vellum and a photo interpreter may extract the detail and create a "map" of lines and symbols and add annotation.

No additional equipment is required. It has been estimated** that the lifting of detail from the orthophoto will triple the man-hours required over that required to produce the unadorned orthophotomap (144 hrs) to around 432 hrs.

A.3 Line Map From Aerial Photography

If a line map is the desired product, an orthophoto need not be created. Standard plotters made by Kelsh, B&L, Wild, Zeiss, Nistri, etc. may be used to prepare line maps directly from the photographs viewed as stereo pairs. The instruments cost approximately $50,000 each, must be operated by good cartographers, and may be used to extract all of the data in the 1500 square area from the photography in approximately 400 to 500 hours***.

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* Line maps, for the purposes of this report, are drafted documents composed of lines and symbols rather than photographic products.

** This very approximate estimate represents the composite average estimates of several cartographic experts at ACIC, AMS-GIMRADA and Geological Survey.

*** Estimate by Mr. J. Steakley, ACIC, regarding an output product with 25 ft. positional accuracy.

A-4 Line-map Revision using Aerial Photography

If a good map exists, but recent photography indicates that vegetation and cultural features are out of date, it is quite a simple matter to revise the land-map. Any of a number of stereo paper-print viewers, such as the Hilger and Watts Stereosketch, permit the revision by photointerpreters of a planimetric manuscript from the local stereo model produced from the photography. The revision might take 40 to 50 hours*; the equipment costs less than $10,000.

A-5 Orthophotomap Revision using Aerial Photography

One must only look at a pictomap to realize that a pleasing revision is not a simple manner. If the digital map developed simultaneously with the original orthophotos is retained, and pass points on the new photography are measured with respect to the digital map control, new orthophoto sections can be produced at the same scale as the existing map and faired-in with automatic dodging equipment. Any of the orthophoto-producing machines could perform this operation as well as the less expensive (approximately $100,000 ~~$35,000~~) Gigas Zeiss and OM1 Orthoprojectors. Other than for mensuration of the photographs and final annotation, no operators are required. Assuming that recontouring is unnecessary, the total mapping time would be a maximum of 120 hrs.

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* ACIC comment: revision requires an order of magnitude less activity than a full compilation.

Appendix B Geological Survey Pictomap Process*

Assuming that the aerial photography has been successfully obtained and that a black and white orthophoto mosaic has been made, the proceedure, based upon the United States Geological Survey method, is as follows: A continuous tone camera negative is created from the orthomosaic, and a contact positive (first generation positive) made as an intermediate step. From it a second generation contact negative, necessary to intensify the graininess and "clumping" of grain structure, is produced, which in turn is used to make the mask positive. The second generation negative is registered back to back with the mask positive and with the emulsion side of the negative contacted to a sheet of film, exposed. The result, known as the Image Tone Positive , similar to the original mosaic, has a random dot pattern which will reproduce in halftone without screening. From this positive a contact litho negative, the Image Tone Negative is made. Normal exposure and development of this will produce press-plates with full range of imagery.

From the same Image Tone Positive another contact negative is made with greater exposure time thereby eliminating all but the deepest shaded areas. Thus, the Accent Tone Negative produces the press-plates for accenting shadows for relief and shape enhancement.

Again, exposing DuPont Contact Reversal CRW Film, emulsion to emulsion, through the same Image Tone Positive, a Surface Tone Reverse Positive is made for highlights. The press plates are made directly from this positive with no intermediate negative.

It is conceivable that the topography or culture in the ortho-photo mosaic could be such that more vigorous line intensification**,

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* The techniques used by the Naval Oceanographic Office for producing Pictomaps have been included in a paper by DeForest D. Choha (reference 6).

** U.S. Geological Survey's "Line Conversion Process"

used either alone or in combination with the image -, accent -, surface-tones would be desirable. In that case, a higher contrast camera negative is made from the original photomosaic. Through it a high-contrast contact positive is exposed as an intermediate step. A second generation contact negative is then exposed through the positive which in turn is used to make the film positive mask. The second generation negative and positive mask are then registered back to back and viewed on a light table. The mask should approximate, but not exceed, a total complement of the negative. Should it not do so a supplementary positive should be added. The registered mask and second generation negativ e are then permanently sandwiched together back to back and a positive exposed in contact with the negative side of the sandwich. Exposure is made on a rotating frame with 60° lighting angle. The product will be a right-reading Line Film Positive without tone. It will show culture, vegetation, drainage, shoreline and limited relief . A Line Film Negative from this would be used for making the press plate.

The Image Tone Negative, Accent Tone Negative and Surface Tone Reverse Positive when registered together will form a composite, enhanced negative version of the original photomosaic with increased clarity of detail and improved definition but still only in black and white. They and/or the Line Film Negative plus cartographic drafted overlays are the buildings blocks of the orthophoto map. Before they are made into press plates they must be further processed and color separated so that earth, water, vegetation, rock, shadow, etc. will be more readily recognized by showing in a natural color. This is the realm of the photointerpreter who must read, translate and evaluate the aerial photograph and assign the correct color and texture to each area using aerial colored photographs, existing maps as well as his own innate knowledge and experience. He and the process photographer must work very closely together to separate these areas correctly by photographic manipulation and masking. It is necessary for the cartographic draftsman at this stage to coordinate his work with theirs in

producing the overlays for annotation, roads, railways, symbols hypsography, nautical data, etc. The overlays must be properly registered to the photographic image and line conflict avoided while colors are chosen for harmony or contrast according to the requirement. The amount of cartographic drafting detail will depend, of course, not only upon the amount of data available but also upon the limited time factor.

Appendix C Central System for Providing Land Maps and Other Services

It is suggested that the survey-ship operations be part of and supported by a land-based base-plant, photographic and logistic operation. The land-based operation is responsible for maintaining a current chart file of known accuracy, directing aerial photographic and hydrographic survey of areas with unsatisfactory coverage, supply to survey ships of latest chart and high altitude photographic information of the coast, and production, as appropriate, of new and revised charts. The following represent a minimum listing of the responsibilities of the land-based operation:

1. Maintain files of planimetry, contours and hydrography of all the coastal areas of the world. The files, which may include both graphic and digital information, should include an evaluation of the accuracy and currentness of the information.

2. Schedule and perform aerial surveys of interesting and important coastal areas on a regular basis. The photography should be developed, printed and filed. The Navy need not fly the photography but is responsible for securing and processing it.

3. Utilize new aerial survey information for new compilations or revisions as indicated and required - servicing particularly the coastal areas scheduled shortly for peacetime hydrographic survey, wartime combat chart production and possible wartime chart production, keeping an entire section of the base plant 100% occupied with this activity. The land-based facility must at least keep up with the photogrammetric requirements of supplying the land coverage required for charting 100 n.m. of shore per week per survey ship. The facility need not supply these chart products themselves; they may get it from the Army or the Air Force

but they must have it on hand to supply to the survey ships before the survey commences.

4. Schedule the operations of the survey ship so as to most efficiently fulfill peacetime (maritime) surveying objectives, sensitive (possible military) objectives, and wartime objectives; in all instances supplying the "survey ships" with color separations (or equivalent) of the latest charts plus a photoindex of the coastal area prepared from high-altitude photography.

5. Accept the inputs from the survey ships (cartographic, photographic plus hydrographic) and, as appropriate, use this information to update charts and prepare new charts.

6. Perform large-quantity reproduction of all charts. The facility must be in position to absorb the new information from the seaborne operation, produce, and dissemenate new chart products in no more than one (1) week, and much faster on a crash basis.